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Stream and Aquifer Biology of South-Central Texas—A Literature Review, 1973–97

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Spotted gar in San Marcos Springs. (Photograph by Dan Misiaszek, San Marcos Area Recovery Team.)

U.S. Department of the Interior
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By Robert T. Ourso and C. Evan Hornig

U.S. GEOLOGICAL SURVEY
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Austin, Texas
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U.S. DEPARTMENT OF THE INTERIOR

Bruce Babbitt, Secretary

U.S. GEOLOGICAL SURVEY

Charles G. Groat, Director

For additional information write to

District Chief
U.S. Geological Survey
8027 Exchange Dr.
Austin, TX 78754–4733
E-mail: dc_tx@usgs.gov

Copies of this report can be purchased from

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, CO 80225–0286
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Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Stream and Aquifer Biology of South-Central Texas—A Literature Review, 1973–97

By Robert T. Ourso *and* C. Evan Hornig

Abstract

This report summarizes in table format 32 aquatic vertebrate (primarily fish), 54 aquatic invertebrate, and 13 aquatic plant studies available for the area of the South-Central Texas study unit of the U.S. Geological Survey National Water-Quality Assessment. The studies, published mostly during 1973–97, pertain to the Guadalupe, San Antonio, and Nueces River Basins, the San Antonio-Nueces and Nueces-Rio Grande Coastal Basins, and the Edwards aquifer where it underlies the upper parts of the three river basins. The biology of the study-unit streams is determined mostly by the characteristics of the ecoregions they transect—the Edwards Plateau, Texas Blackland Prairies, East Central Texas Plains, Western Gulf Coastal Plain, and Southern Texas Plains.

About 20 percent of the previous fish and invertebrate studies and about 75 percent of the aquatic plant surveys have centered on Comal Springs in Comal County and San Marcos Springs in Hays County. Although several important studies are available for the San Antonio region, documentation of aquatic biology for the remainder of the study unit is relatively sparse. The streams in the study unit, particularly in the Edwards Plateau, support three dominant biological groups—fish, aquatic invertebrates, and plants. Potential threats to these organisms include impoundments and flood-control projects, siltation from erosion, ground-water pumping, recreational activities, wastewater discharge, and introduction of non-native species. More than 30 non-native fish, invertebrate, and plant species have been introduced into the region. Of the 19 aquatic species Federally listed as endangered or threatened in Texas, 8 are associated with springs and spring runs in the study unit. All of the endangered species in the study unit are associated with springs and spring runs.

A large number of endemic species in the study unit are associated with subterranean aquatic ecosystems, most likely a consequence of the unique proximity of the varied topographic and hydrologic conditions of the area and of the geological development of the Edwards aquifer. Ninety-one endemics, including 44 species found solely underground, are associated with the aquatic ecosystems (including springs) of the Edwards aquifer.

INTRODUCTION

The U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program began in 1991 to assess many of the Nation's major river basins and aquifers. The Program is designed to produce technically sound descriptions regarding the status of and the trends in the resource quality of these aquatic systems. NAWQA also is designed to increase the understanding of the natural and human factors that affect these water resources and to link this understanding with the observed status and trends. The nationally consistent, integrated assessment of chemical, physical, and biological resources will provide water managers and policy makers with information for directing water-quality management programs and for evaluating the effectiveness of these programs. Gilliom and others (1995) present a complete description of the NAWQA objectives and design.

The building blocks of the NAWQA Program are study-unit investigations. The study units selected encompass one or more major river basins and aquifers. When fully implemented, there will be more than 50 study units distributed across the Nation. Combined, they encompass about one-half of the conterminous United States and 60 to 70 percent of the population and national water use. One-third of the study units are intensively studied for 3 years on a rotational basis

with each of the other two groups of study units, resulting in each study unit being revisited for intensive study on 9-year cycles. The NAWQA study unit addressed in this report is the South-Central Texas (SCTX) study unit (fig. 1), which includes the Guadalupe, San Antonio, and Nueces River Basins; two minor coastal basins; and the Trinity, Edwards, Carrizo-Wilcox, and Gulf Coast aquifers where they underlie the three river basins.

In addition to intensive field investigations, retrospective reports of existing environmental data are prepared at study-unit and national levels to improve the understanding of historical and present conditions of the water resources and to help interpret results from the intensive field investigations. Retrospective synthesis of existing stream and aquifer biological data for the SCTX study unit is addressed in this report.

Uses of Aquatic Biological Data

Biological monitoring is widely used to assess water resources, both as an integrative assessment tool and as the only direct method to determine instream attainment of State water-quality standards for aquatic life use. These standards are assigned to most U.S. surface waters. To determine instream attainment of these standards, some states have incorporated biological criteria into State water-quality criteria and regulations (Davis and others, 1996). These criteria are either narrative descriptions, such as lists of fish species, or numerical expressions (metrics) of aquatic life variables, including diversity indices and pollution tolerance values (U.S. Environmental Protection Agency, 1996).

Biological monitoring serves as an integrative assessment tool in two ways: (1) The type and condition of organisms reflect the overall health of the aquatic resources (Karr, 1995), and (2) the relatively stationary nature of many aquatic organisms signifies their ability to integrate environmental conditions over time, thereby reducing frequency of sampling needed to detect changes (Hynes, 1960).

Combining biological monitoring with physical and chemical data can be used to develop a comprehensive and efficient approach to water-quality surveillance (Hornig, 1984). Initial surveys of one or more components of the resident biota (typically fish, invertebrates, or plants) provide evaluations of the overall quality of the water resources. When results from these initial surveys indicate biological impairment, follow-up analyses (chemical, habitat, or more intensive biological studies) are done to determine the extent and probable causes. Biological monitoring also can be used to measure the success of restoration and the subsequent attainment of water-quality standards.

Reference-site or paired-site monitoring helps factor out annual area-wide variations in the biota, improving the ability to distinguish localized (typically human-caused) effects from regional (typically climatic) effects. Reference sites are the least impaired sites in a specific geographic region and serve as “benchmarks” for evaluating the stream quality at other sites. State water-quality agencies use biological data at reference sites to develop the biological criteria used to determine attainment of water-quality standards for aquatic life use (Hornig and others, 1995).

The USGS recognizes the critical role of biological and habitat data for comprehensive assessment of aquatic environments by water-resource managers. When complemented with chemical constituent data and land use information, biological and habitat data can be useful for identifying the natural and human factors affecting current conditions and the trends in aquatic-resource quality (Cuffney and others, 1997).

Purpose and Scope

This retrospective report summarizes information on aquatic biology of the streams and rivers in the Guadalupe, San Antonio, and Nueces River Basins and the San Antonio-Nueces and Nueces-Rio Grande Coastal Basins, and of the Edwards aquifer where it underlies the three river basins. (Aquatic biological information on the Trinity, Carrizo-Wilcox, and Gulf Coast aquifers is not included.) The report contains lists and distributions of fish and aquatic invertebrates, and lists of aquatic plants, aquifer organisms, non-native aquatic species, and endangered aquatic species. The report identifies sources of information on the biology of the streams and rivers and of the aquifer. Maps are provided to identify studies in specific areas. The report summarizes major publications, serving as a “one-stop” resource for historical aquatic biological data (prior to 1998) for this region.

Sources of Biological Data

Primarily Federal, State, and academic organizations have collected biological data from river basins in the SCTX study unit. The studies and reports of the U.S. Fish and Wildlife Service (USFWS), Texas Natural

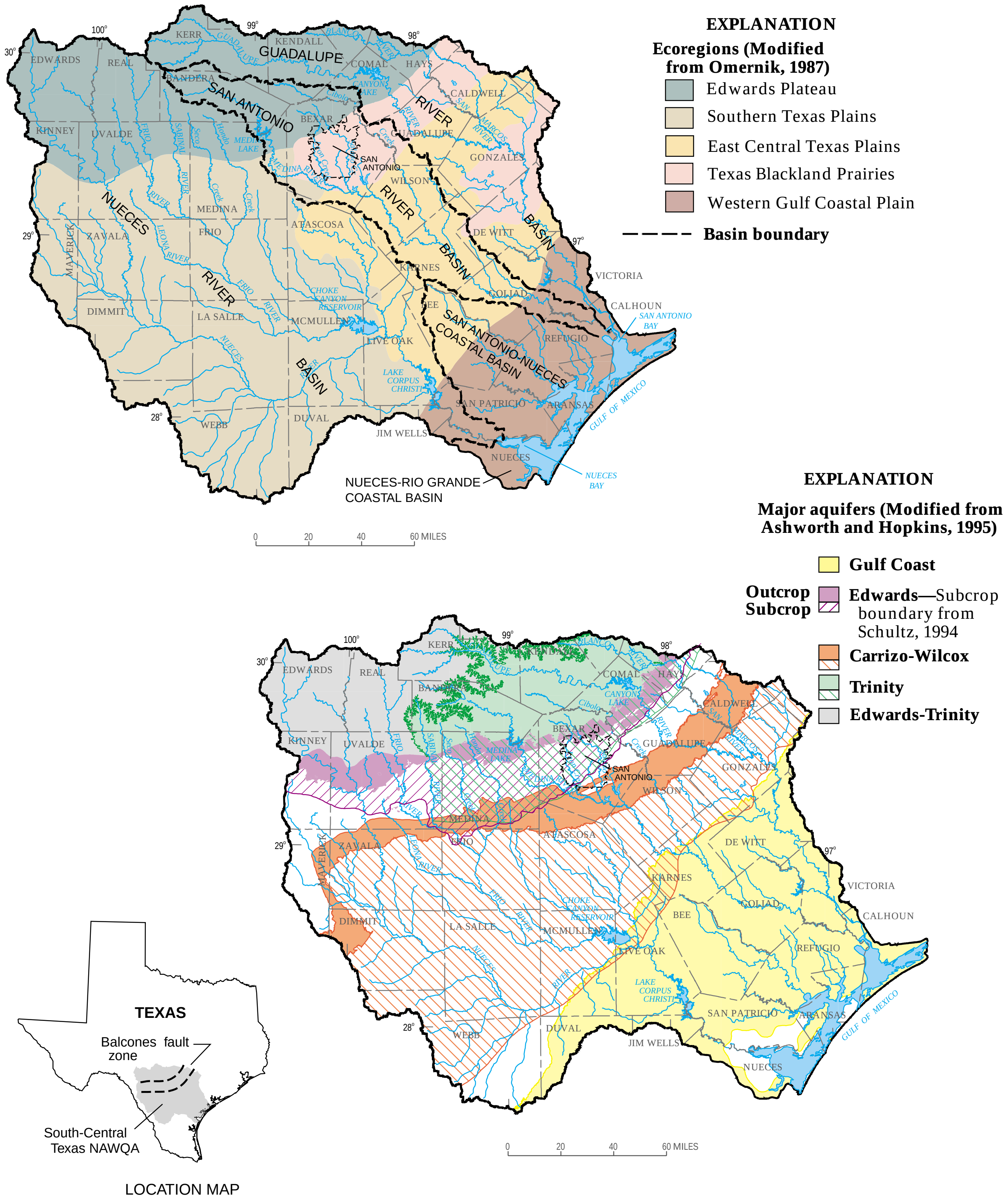


Figure 1. Surface-water basins, ecoregions, and major aquifers of the South-Central Texas study unit, Texas.

Resource Conservation Commission (TNRCC), Texas Parks and Wildlife Department (TPWD), San Antonio River Authority, Southwest Texas State University, and University of Texas provide most of the information in this report. This report emphasizes biological surveys that mostly were published after 1972. Young and others (1973) provide a compilation of information collected prior to 1973.

Acknowledgments

The authors thank their colleagues at the U.S. Fish and Wildlife Service, Texas Natural Resource Conservation Commission, Texas Department of Parks and Wildlife, San Antonio River Authority, Southwest Texas State University, and University of Texas, who have been instrumental in providing literature and biological data cited in this report.

SOUTH-CENTRAL TEXAS STUDY UNIT

The SCTX study unit is located in south-central Texas, encompassing the Guadalupe, San Antonio, and Nueces River Basins, two minor coastal basins, and the Trinity, Edwards, Carrizo-Wilcox, and Gulf Coast aquifers where they underlie the three river basins (fig. 1). This region of Texas contains a diversity of both surface-water and aquifer habitats. In addition to lakes and streams of various sizes and geomorphic types, the Edwards aquifer and associated springs provide habitat to a variety of unique aquatic species.

Surface-Water Basins and Ecoregions

The SCTX study unit, with a drainage area of about 30,000 square miles (mi^2), encompasses parts of five ecoregions (fig. 1). The ecoregions, as described by Omernik (1987), are the Edwards Plateau, Texas Blackland Prairies, East Central Texas Plains, Western Gulf Coastal Plain, and Southern Texas Plains. The study unit has a wide variety of climatic, geologic, topographic, and hydrologic conditions. The proximity of ecoregions with different characteristics (fig. 1) makes the study unit a “convergent zone” of soil, climatic, topographic, and biotic features. Detailed descriptions of the flora, fauna, and land use are in Blair (1950) and Gould (1975).

The biology of the study-unit streams is determined mostly by the characteristics of the ecoregions they transect. Aquatic life is similar in the upper reaches of each of the three major river basins, as these reaches are within the Edwards Plateau ecoregion. The mostly spring-fed streams in this ecoregion have stable bottom substrates, well-vegetated streambanks, and cool, clear water year round. Invertebrate taxa richness and other measures of aquatic life health used by the TNRCC are consistently greater in central Texas than other regions of the State (Hornig and others, 1995). Invertebrate samples collected from the streams in this area have included more than 50 taxa from 3 square feet (ft^2) of stream bottom (Bayer and others, 1992).

The habitat and accompanying biota of the streams in the study-unit basins change substantially in the downstream reaches. The SCTX study unit extends into the Southern Texas Plains (to the southwest), the East Central Texas Plains and Western Gulf Coastal Plain (to the southeast), and the Texas Blackland Prairies (to the east). The streams in these ecoregions are characterized by warm, turbid water; dominated by soft-bottom runs and pools (with only occasional riffles); and bordered by highly erodible streambanks (Bayer and others, 1992). Warm-water, stress-tolerant species predominate in the streams of these ecoregions.

Guadalupe River Basin

The Guadalupe River originates in Kerr County at about 1,800 feet (ft) above mean sea level and joins the San Antonio River 11 miles (mi) upstream from Guadalupe Bay (part of San Antonio Bay) (fig. 1). The river is about 410 mi long with a drainage area of about 6,000 mi^2. The 30-year (1961–91) normal precipitation in the basin ranges from about 30 inches (in.) near the headwaters to about 40 in. near the coast (Dallas Morning News, Inc., 1997, p. 113–118). Annual mean discharge of the Guadalupe River into Guadalupe Bay is 1,867 cubic feet per second (ft^3/s) (on the basis of 1935–97 water-year records at USGS streamflow-gaging station 08176500 Guadalupe River at Victoria (Gandara and others, 1998)). Canyon Dam, forming Canyon Lake (fig. 1), was completed in 1964 for flood control, water storage, hydroelectric power generation, and recreational uses. With the closing of the dam, the Guadalupe River became a regulated river over much of its length, rarely subject to the wide range of natural flows that are typical of this region. Daily mean discharge from Canyon Dam ranges from 0.80 to 5,680 ft^3/s, and annual mean discharge is 457 ft^3/s (on the basis of 1963–97 water-year records, the period of regulated streamflow, at USGS streamflow-gaging

station 08167800 Guadalupe River at Sattler (Gandara and others, 1998)). The San Marcos River, with its confluence to the Guadalupe River in Gonzales County (fig. 1) provides the only regular input of substantial flow below Canyon Dam. The San Marcos is a spring-fed river; annual mean discharge from the springs is 170 ft^3/s (on the basis of 1957–94 water-year records at USGS streamflow-gaging station San Marcos River springflow at San Marcos (Gandara and others, 1995)). During periods of little or no precipitation, which result in low streamflows in other streams in the basin, the San Marcos River is the major contributor of streamflow in the Guadalupe River.

San Antonio River Basin

The San Antonio River (fig. 1) originates in metropolitan San Antonio (1996 estimated population 1.1 million (Dallas Morning News, Inc., 1997)) at about 690 ft above mean sea level. The river flows southeasterly for about 240 mi from the headwaters to its confluence with the Guadalupe River north of Guadalupe Bay, and has a drainage area of about 4,300 mi^2. The 30-year normal precipitation in the basin is similar to that in the Guadalupe River Basin. The annual mean discharge of the San Antonio River to the Guadalupe River near Guadalupe Bay is about 723 ft^3/s (on the basis of 1924–97 water-year records at USGS streamflow-gaging station 08188500 San Antonio River at Goliad (Gandara and other, 1998)). Stream quality of the San Antonio River is affected a short distance downstream of the headwaters by numerous municipal and industrial wastewater discharges and by urban runoff. During low-flow conditions, flow is predominantly treated wastewater. The Medina River (fig. 1) is a major tributary of the San Antonio River. Annual mean discharge of the Medina River is 206 ft^3/s (on the basis of 1939–97 water-year records at USGS streamflow-gaging station 08181500 Medina River at San Antonio (Gandara and others, 1998)). Salado, Leon, and Cibolo Creeks (fig. 1) are minor tributaries that contribute little to the base flow of the San Antonio River. Cibolo Creek begins as a spring-fed creek in the Edwards Plateau, contributing recharge to the Edwards aquifer as it flows across the aquifer recharge zone.

Nueces River Basin

The Nueces River Basin (fig. 1) is the largest of the three major basins in the study unit. The Nueces River originates in Edwards County at about 1,600 ft above mean sea level and flows about 440 mi from the headwaters to its mouth at Nueces Bay. The 30-year normal precipitation (1961–90) in the basin ranges from 21 in. in the upper basin to 35 in. near the coast (Dallas Morning News, Inc., 1997, p. 113–118). Although the Nueces River has a large drainage area (about 17,000 mi^2), it has the smallest annual mean discharge of the three major rivers in the study unit—135 ft^3/s (on the basis of 1939–97 water-year records at USGS streamflow-gaging station 80192000 Nueces River below Uvalde (Gandara and others, 1998)). The Nueces River and its upstream tributaries, including the Frio and Sabinal Rivers and Seco and Hondo Creeks, originate from seeps and springs in the Edwards Plateau. As the streams cross the Balcones fault zone to the south (fig. 1), a substantial amount of flow from these streams enters the Edwards aquifer. The Nueces River is the only stream in the basin that regularly maintains some flow beyond the recharge zone. Mostly erratic rainfall provides much of the streamflow for the Nueces River and its tributaries south of the Balcones fault zone, with periods of no flow in the lower reaches of the Nueces River.

Minor Coastal Basins

Two minor basins in the SCTX study unit drain coastal areas directly into the Gulf of Mexico. Streamflows in these basins are primarily dependent on precipitation. The San Antonio-Nueces Coastal Basin has a drainage area of about 2,600 mi^2, and the Nueces-Rio Grande Coastal Basin has a drainage area of about 280 mi^2. The 30-year (1961–90) normal precipitation in the coastal basins ranges from about 30 to 40 in. (Dallas Morning News, Inc., 1997, p. 113–118).

Edwards Plateau Ecoregion

The Edwards Plateau ecoregion, encompassing about 6,500 mi^2 (25 percent of the study unit), also is known locally as the Edwards Plateau or Texas Hill Country. The topography is hilly with elevations from 800 ft to more than 1,800 ft above mean sea level and is commonly incised by streams. The Edwards Plateau receives 16 to 33 in. of precipitation annually, increasing from west to east (Gould, 1975). Soils are mostly shallow, underlain by limestone or caliche. Typical land use is grazed open woodland, grazed forest, and woodland; some subhumid grassland; and semiarid grazing (Anderson, 1970).

Texas Blackland Prairies Ecoregion

The Texas Blackland Prairies ecoregion encompasses about 2,700 mi^2 (8.7 percent of the study unit). The topography of the region is gently rolling to relatively flat, with elevations from 300 to 800 ft above mean sea level. The region is well dissected by streams, which allow for rapid drainage. Soils associated with this region are fairly uniform, dark-colored calcareous clays interspersed with some gray, acid sandy loams. Annual precipitation varies from 30 in. for the western part to more than 40 in. for the eastern part (Gould, 1975). Land use is primarily cultivated cropland (Anderson, 1970).

East Central Texas Plains Ecoregion

The East Central Texas Plains ecoregion encompasses about 5,500 mi^2 (18 percent of the study unit). The region consists of rolling to hilly landscapes with elevations from about 300 to 800 ft above mean sea level. Annual precipitation varies from 35 to 45 in. (Gould, 1975). Soils range from acid sandy loams or sands to clays. Land use is typically woodland with some cropland and pasture (Anderson, 1970).

Western Gulf Coastal Plain Ecoregion

The Western Gulf Coastal Plain ecoregion encompasses about 3,400 mi^2 (11 percent of the study unit). This poorly drained plain is less than 150 ft above mean sea level and is dissected by streams flowing into the Gulf of Mexico. Annual precipitation varies from about 20 in. for western areas to about 50 in. for eastern areas (Gould, 1975). Soils are acid sands, sandy loams, and clays. Cropland and cropland with grazing are the dominant land uses (Anderson, 1970).

Southern Texas Plains Ecoregion

Encompassing about 12,000 mi^2 (35 percent of the study unit), the Southern Texas Plains is the largest ecoregion in the study unit. The topography is level to rolling hills with elevations from about 0 to 1,000 ft above mean sea level. Annual precipitation varies from 16 in. for the western part to 35 in. for the eastern part (Gould, 1975). Soils range from clays to clay loams. Predominant land use is grazed open woodland, subhumid grassland, and semiarid grazing land (Anderson, 1970).

Edwards Aquifer Habitats

The western part of the Edwards aquifer, known as the San Antonio region, extends from Hays County to Kinney County within the SCTX study unit. The deposition of the material that became the carbonate rocks of the Edwards aquifer began almost 100 million years ago in a shallow sea. Repeated submergence and exposure of the carbonate rocks allowed early formation of cavernous porosity. Hundreds of feet of sediments were deposited over this early aquifer, and as the North American continent was slowly uplifted, the Cretaceous seas began to recede, allowing streams to cut into the sediments and expose the underlying Edwards aquifer. A period of extensive faulting during the Miocene (12 to 17 million years ago) resulted in the formation of the Balcones fault zone. With the changes imposed by the new faults, new ground-water movement was manifested in some areas as recharge points and in other areas as resurgence points or springs (Longley, 1986).

The high permeability of the Edwards aquifer results from the freshwater diagenesis of faulted and fractured carbonate rocks. After the rocks were broken and displaced during the Balcones faulting, large quantities of freshwater infiltrated strata that previously had been isolated from the surface (Kastning, 1983). Subsequent faulting processes were initiated that eventually provided an extremely transmissive (fast-moving) ground-water-flow system (Abbott, 1975). The present-day aquifer is riddled with joint cavities and solution channels (caverns) that have evolved through erosional unloading and dissolution. The outcrop area has a porous, honeycombed, or Swiss cheese appearance because of the preferential leaching of soluble materials (Barker and Ardis, 1996).

Many wells penetrate caverns in the area around San Antonio (Livingston, 1947; Petitt and George, 1956). It is estimated that in 1975, wells and springs in Bexar County discharged 259.0 thousand acre-feet (acre-ft) of water from the Edwards aquifer, with about 15 percent of this discharge from springs (Rappmund, 1976, p. 5). In reviewing publications on the hydrology of the Bexar County area, Petitt and George (1956) noted that the well logs of a large percentage of the wells in the San Antonio area included some cavernous areas. These areas could provide sufficient space for propagation of aquatic organisms.

The USGS and various Texas water agencies have conducted analyses on the chemical quality of the Edwards aquifer in the San Antonio region (Garza, 1962; Pearson and Rettman, 1976; Reeves, 1976; Reeves and others, 1972). In general these publications provide information on the geochemistry of the area.

Other publications give insight into how the water movement occurs within the Edwards aquifer in the San Antonio region (Abbott, 1977; Maclay and Small, 1976; Pearson and Rettman, 1976; Pearson and others, 1975; Puente, 1976). In general, the movement in the aquifer is from the west to the east or northeast. Numerous publications discuss the hydrology of the aquifer specifically and include water levels, recharge, discharge, amounts of precipitation, and other hydrologic properties (Follett, 1956; Garza, 1966; Lang, 1954; Maclay and Rettman, 1973; Puente, 1974; Rappmund, 1975, 1977; Rettman, 1969; Sieh, 1975). Hydrologic models have been developed for predictive purposes on the basis of increased population and subsequent increased water use. These models indicate that without additional recharge, the average water level in the aquifer will continue to drop in the future (Wanakule, 1988). Other than a reduction in springflow, it is not clear how water-level declines would affect the availability of habitats for spring and aquifer organisms in the region.

STREAM BIOLOGY

The three most dominant biological groups that typically form stream communities are fish, aquatic invertebrates (chiefly arthropods, molluscs, and segmented worms), and attached algae (the primary producers). The fish and invertebrates include species specialized as primary consumers (of the algae), as detritivores (shredders of terrestrial debris entering the stream or filterers and gatherers of fine organic particles), and as predators. Other species are omnivorous—opportunistic consumers of several food sources. Aquatic species also have specific habitat requirements; a stream community will be determined largely by the available habitat (stony riffle, sandy run, or soft-bottom pool). The condition of the habitat (including embeddedness of stones, amount of cover from instream structures and streambank features, and contaminants in bottom sediments and food) and the quality of the water (temperature, light, pH, conductivity, dissolved oxygen, nutrients, and dissolved and suspended solids) can affect the distribution of aquatic organisms. Other factors that affect the distribution of organisms include dispersal (proximity of colonization areas or downstream barriers such as dams), predation and competition from native and introduced species, food sources from upstream and terrestrial inputs, and hydrologic conditions such as floods and droughts.

The resident stream biota reflect both the current and recent conditions of the habitat, water-quality, and hydrologic factors. In general, algae integrate the previous days to weeks of conditions, and invertebrates can reflect conditions during their lifespans of several months to a year; and fish can reflect previous conditions for as much as several years. The biological groups also differ in the specificity of the environment they reflect: The less-mobile algae and invertebrates reflect recent conditions within a specific pool, run, or riffle, and the more-mobile fish can integrate conditions over much greater distances.

Vertebrate Communities

Thirty-two studies of vertebrates (primarily fish) in streams in the SCTX study unit published mostly during the 1980s and 1990s are summarized in table 1 (at end of report). The locations of many of the studies (those with specifically identifiable sampling sites) are shown in figures 2 and 3. The majority of the reports list taxa and numbers of fish for the study sites. When coupled with the report by Young and others (1973), an extensive amount of fish data are available for the study unit. About 140 fish species from the SCTX study unit are listed by the Texas System of Natural Laboratories, Inc. (1994) (table 2, at end of report).

Hubbs (1957) suggested that the distribution of fish closely follows climatological and geologic factors because these factors affect the chemical and physical properties of aquatic systems. The SCTX study unit is a highly diverse assemblage of environments controlled by the wide variety of climatic, topographic, soil, and biotic factors in the region (Blair, 1950; Gould, 1975). In the analysis of fish collections from eastern and central Texas in 1953 and in 1986, Anderson and others (1995) showed the relative region-wide stability in species diversity during 33 years. Despite this encouraging trend, the report indicated that, for localized areas, several species had become extinct or endangered.

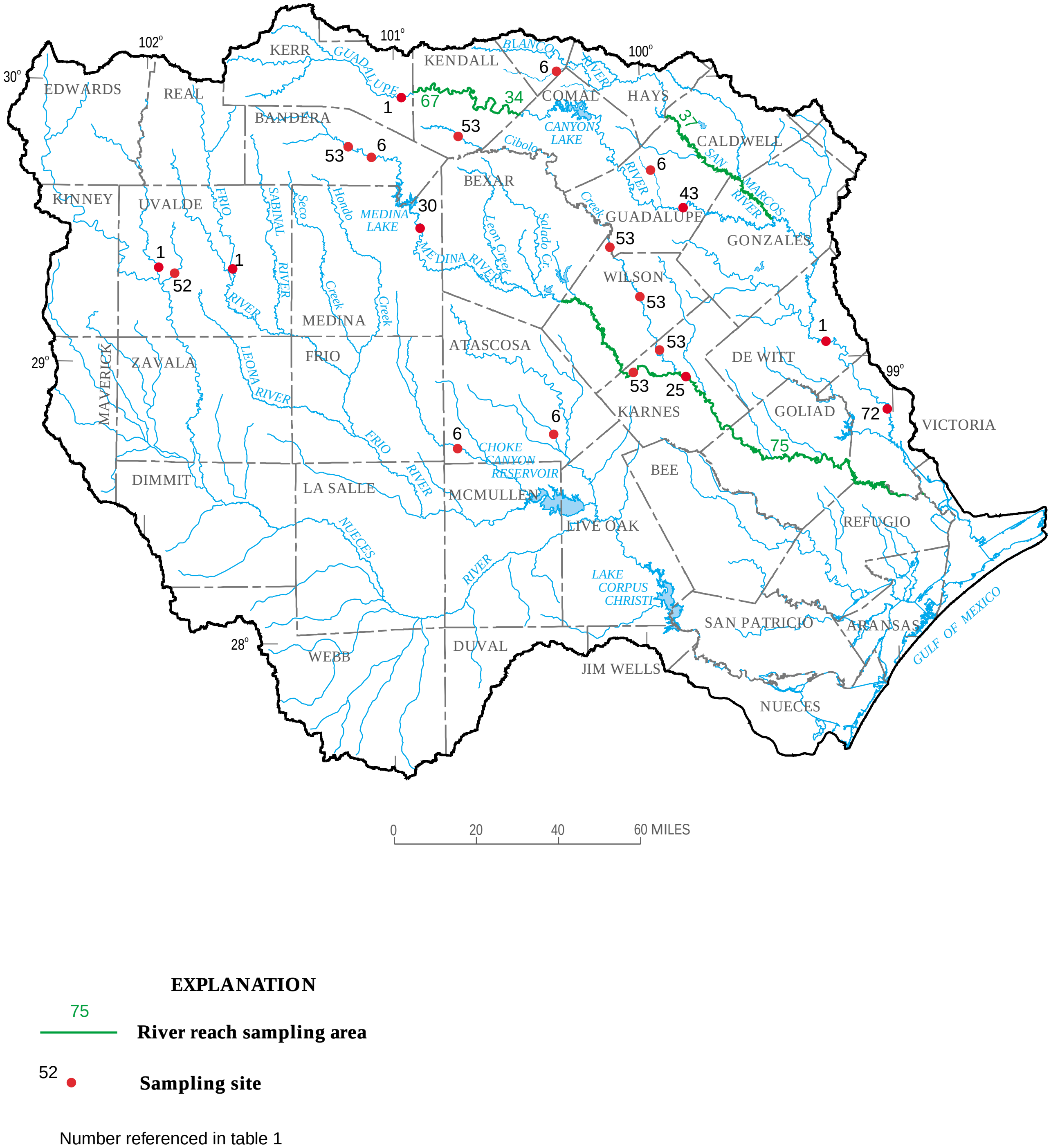


Figure 2. Locations of previous fish studies in the South-Central Texas study unit, Texas.

Invertebrate Communities

Fifty-four studies of aquatic invertebrates published during 1971–97 are summarized in table 1. The locations of most of the studies (those with specifically identifiable sampling sites) are shown in figures 4 and 5. Surveys, species composition reports, and theses make up the majority of studies concerning invertebrates in the study area. Most of the reports list taxa and numbers of invertebrates collected at the study sites. Although aquatic vertebrates in Texas have been well documented (Hubbs and others, 1991), complete species inventories for most groups of aquatic invertebrates

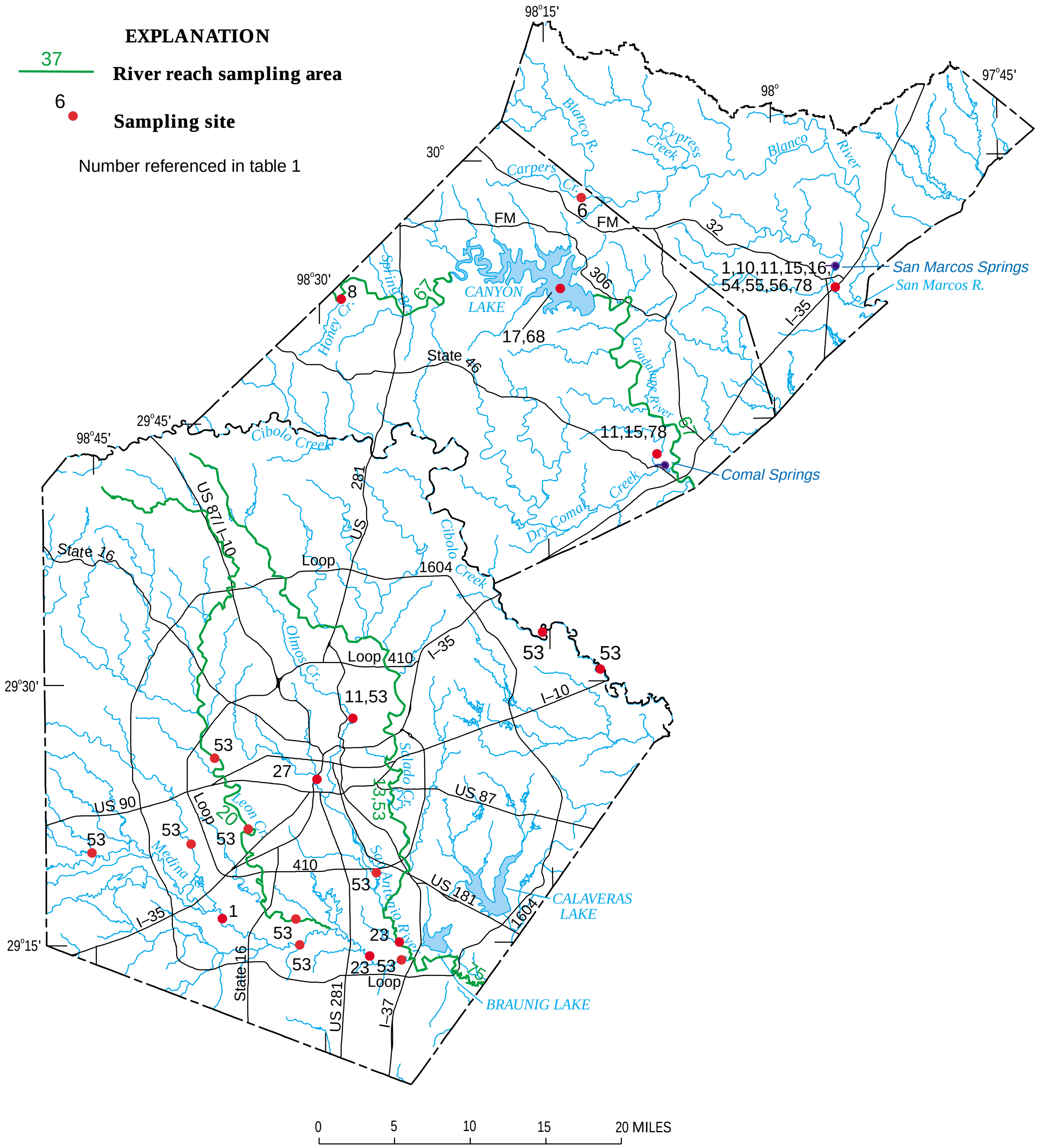
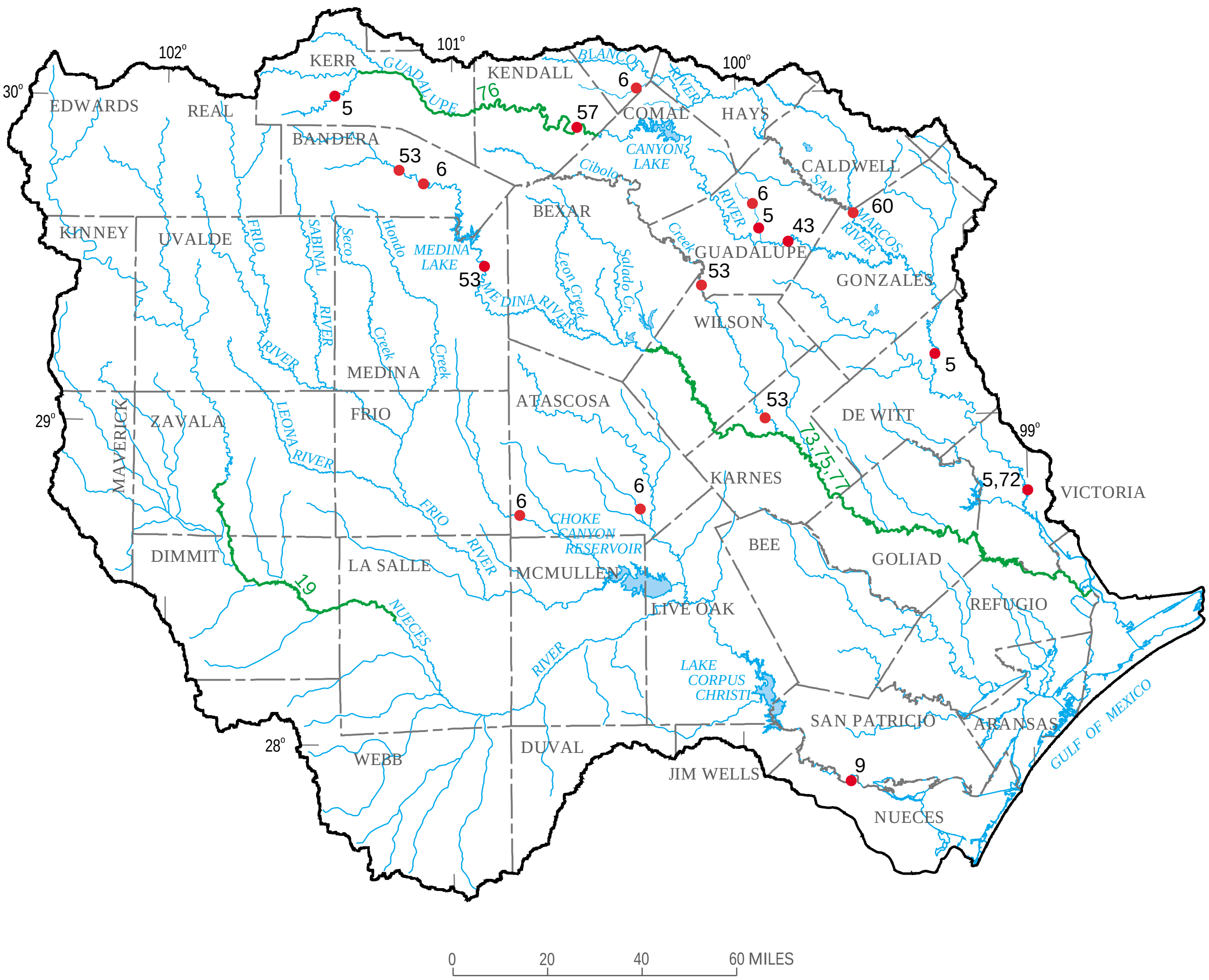


Figure 3. Locations of previous fish studies in Bexar, Comal, and Hays Counties, Texas.

are lacking (Bowles and Arsuffi, 1993). One of the more complete recent studies catalogued invertebrates from the least-impacted streams of the Texas ecoregions (Bayer and others, 1992). About 180 aquatic invertebrate species were collected from the SCTX study unit (table 3, at end of report).

Plant Communities

Thirteen studies of plant communities published during 1940–97 are summarized in table 1. The majority of the reports are listings of taxa or distributions within the study unit. There also are secondary



EXPLANATION

19 — **River reach sampling area**

6 ● **Sampling site**

Number referenced in table 1

Figure 4. Locations of previous aquatic invertebrate studies in the South-Central Texas study unit, Texas.

references to plant communities and their role as habitat for, or impact on, endangered species (Bowles and Arsuffi, 1993; Power, 1996). Macrophytes are the focus of all the plant studies listed in table 1 partly because of the importance of macrophytes in Comal and San Marcos Springs, the two largest springs in Texas. About 30 aquatic plants have been identified in the study unit (table 4, at end of report).

Species of Concern

Threats to the continued existence of aquatic endemics (native species unique to the area) typically

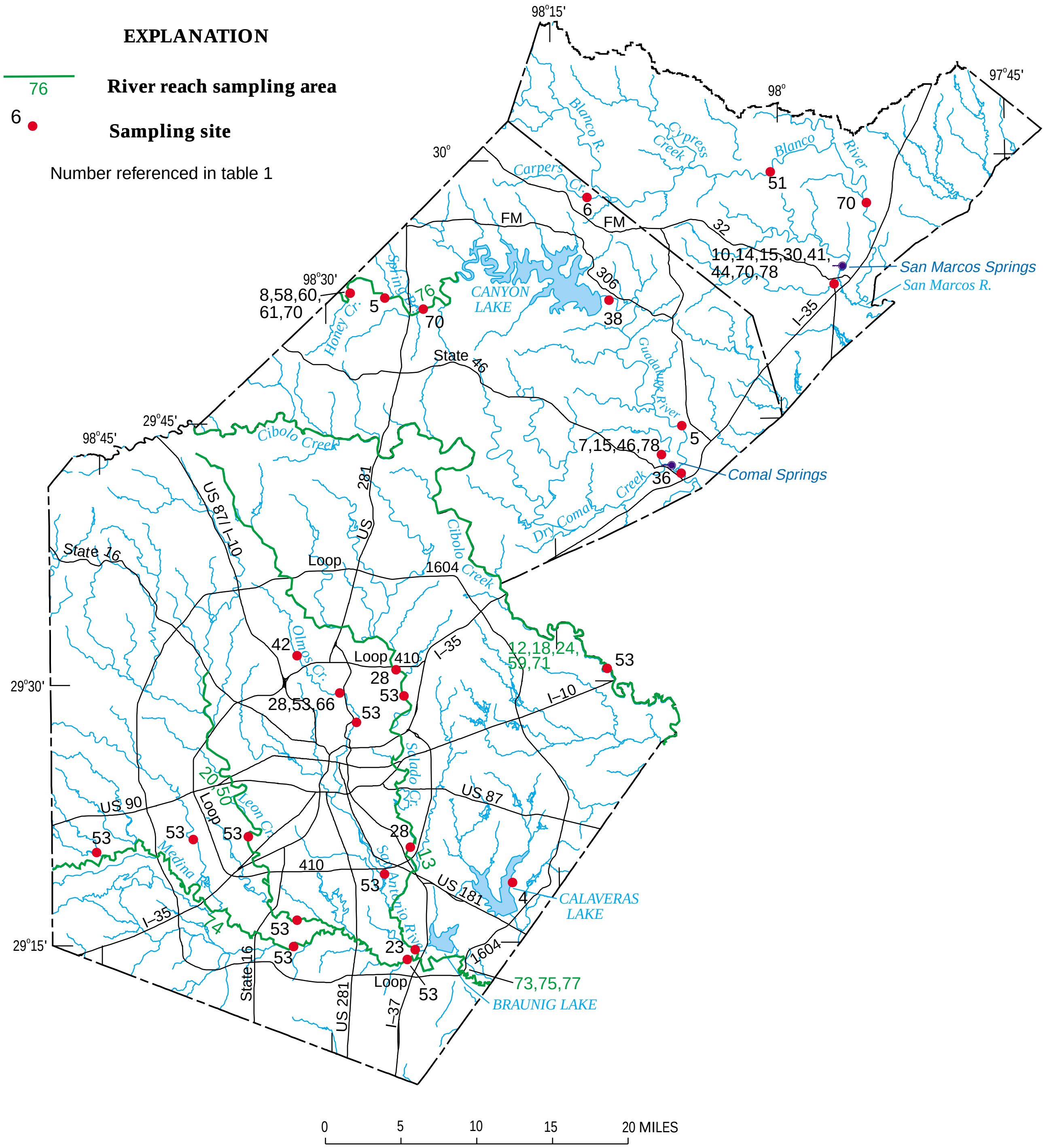


Figure 5. Locations of previous aquatic invertebrate studies in Bexar, Comal, and Hays Counties, Texas.

are anthropogenic and include "agricultural practices, impoundments and flood-control projects, siltation from erosion, ground-water pumping, introduction of non-native species, recreational activities, waste-water discharge, and general pollution" (Bowles and Arsuffi, 1993, p. 320). Allan and Flecker (1993, p. 35) listed six factors as critical in flowing water systems: "habitat loss and degradation, the spread of non-native species, overexploitation, secondary extinctions (loss of a species resulting from loss of one or more other species), chemical and organic pollution, and climate change." With respect to non-native species,

they suggest that more tolerant invaders might gain a foothold because of favorable conditions, reduction of the native fauna population, or alteration and degradation of habitat.

Introduced Species

Non-native species, that is, those species introduced into an area outside their natural range (or in the case of “exotic” species, from outside the continent) present a threat to Federally listed (endangered or threatened) species and their habitat (U.S. Fish and Wildlife Service, 1995). Competition, predation, hybridization, and habitat modification by non-natives have been identified as major factors threatening endemic organisms (Bowles and Arsuffi, 1993; Ono and others, 1983; U.S. Fish and Wildlife Service, 1995). The SCTX study unit has more than 30 known non-native aquatic species (table 5, at end of report), many of tropical origin. Their ability to survive cold winters often relates directly to the minimum annual water temperature. For example, exotic giant ramshorn snails (*Marisa cornuarietis*) have been shown to withdraw into their shells and collect on the bottom substrates at 19 degrees Celsius (°C). These organisms die within 5 hours upon exposure to a temperature of 8 °C (Robins, 1971), thereby effectively limiting their range. Most spring-fed streams in the study unit have temperature ranges within 1 °C and thus provide suitable habitat for these snails and many other tropical species that would otherwise die from minimum winter temperatures (Hubbs, 1995). The introduction and subsequent survival of the blue tilapia (*Tilapia aurea*) into heated power-plant effluent reservoirs and into the spring-fed upper reaches of the San Marcos, Comal, and San Antonio Rivers (Hubbs and others, 1991) is an excellent example of this phenomenon.

Endangered and Threatened Species

Hubbs and others (1991) estimated that 20 percent of the 169 native Texas freshwater species are in potential danger of extirpation (range reduction) or extinction. Of the 19 aquatic species listed in Texas by the USFWS as endangered or threatened, 8 are associated with the SCTX study unit. Table 6 (at end of report) lists the species considered to be of concern (proposed for listing, endangered, or threatened) in Texas by the USFWS, TPWD, or by the Texas Organization for Endangered Species (TOES). Endangered and threatened species are at the center of a complex battle over water rights within the study unit. The San Marcos and Comal Springs and Associated Aquatic Ecosystems Recovery Plan (revised) was developed to ensure the survival of listed species in their native systems through an ecosystem approach to the recovery of multiple species (U.S. Fish and Wildlife Service, 1995). The San Marcos gambusia (*Gambusia georgei*) is presumed extinct (Miller and others, 1989), and its case is indicative of the problems of many of the endemics throughout the study unit. Its habitat was restricted to the upper San Marcos River (spring run) where, even historically, the organism was rare and difficult to find. Ono and others (1983) list habitat alteration, pollution, and competition with the introduced *Gambusia affinis* as the probable causes for the extinction of *G. georgei*. This species has not been collected in the wild since 1982 (Hubbs and others, 1991).

All of the Federally listed endangered species in the study unit are associated with springs and spring runs, thereby emphasizing the importance of conservation of these habitats. Hubbs (1995) noted that spring fish seldom are found at any substantial distance from the springs and that the area occupied by the endemics is related directly to the volume of water flowing from the springs. Hubbs also reported that droughts reduce available habitats.

AQUIFER BIOLOGY

Strayer (1994) noted that the Edwards aquifer in the SCTX study unit is one of a few regions in the world where a large diversity of subterranean species are found. Longley (1981) reported that the Edwards aquifer might be the most diverse subterranean biological community on earth. The list of species associated with the aquifer is large and is expected to grow as more faunal studies are completed. Both vertebrate (salamanders and two species of blind catfish) and invertebrate troglobitic (restricted to ground-water habitats) species have been found within this aquifer. Ninety-one species or subspecies, including 44 troglobitic species, have been identified as endemic to the aquatic ecosystems (including springs) associated with the Edwards aquifer (Barr and Spangler, 1992; Bowles and Arsuffi, 1993; Longley, 1986). Table 7 (at end of report) lists the known endemic troglobitic species of the Edwards aquifer.

Longley (1986) reported that the biological invasion of the Edwards aquifer probably began during the deposition of the Edwards Limestone more than

100 million years ago. Alternate periods of submergence and exposure of the region by the shallow Cretaceous sea allowed early formation of caverns. At least 10 crustaceans found in the Edwards aquifer are related to typically marine species and likely evolved from the marine environment that last covered the area during the late Cretaceous or early Tertiary (65 to 70 million years ago) (Holsinger and Longley, 1980).

About 12 to 17 million years ago, during the Miocene, a period of extensive faulting in south-central Texas began that resulted in the subsequent formation of the Balcones fault zone, changing the movement patterns of ground water within the Edwards (Longley, 1986). This faulting created new springs and points of surface-water entry (recharge) into the ground water (Barker and Ardis, 1996), providing many new entry locations for the freshwater species of south-central Texas. During this time, further dissolution of the limestone increased cavernous porosity in the limestone; this increased formation of caverns in the limestone, and the linkage between caverns created new habitat and distribution patterns for the area ground-water species. Langecker and Longley (1993) believe extensive cave development during the Miocene could have allowed colonization of the ancestors of the two species of blind catfish presently in the Edwards aquifer. Langecker and Longley (1993) conclude that the morphological adaptations of these fish, including degree of eye reduction, are evidence that these fish are among the oldest known cave fish.

Invasions of an aquifer by freshwater organisms are most likely during periods of environmental stress (Holsinger, 1988). Longley (1986) indicated that the onset of the ice age 3 million years ago had a major influence on the biology of the Edwards aquifer. During extremely cold periods, the ground water maintains constant temperature and offers a refuge for aquatic organisms. Severe droughts in the region also could have contributed to the invasion of the Edwards; in particular, the ground-water salamanders of Central Texas could have migrated into cave streams when their surface habitats dried up (Sweet, 1982).

Because of the lack of light within the aquifer, food derived from photosynthesis is not available to the ground-water communities. In the area near San Marcos Springs, where the aquifer habitat is near the recharge zone, organic debris washed in from the surface is the source of energy to the primary consumers, chiefly amphipods, shrimp, and snails (Browning, 1977; Longley, 1981). Here the blind salamanders are at the top of the food chain; captive specimens have been observed feeding on a variety of aquifer invertebrates (Longley, 1981). Another likely predator is a blind species of the predaceous diving beetle family.

In deeper parts of the aquifer (1,300 to 2,000 ft) near San Antonio, the organic matter brought in from distant recharge areas would not be sufficient to support the aquifer biota. Instead, it has been theorized that fossil organic matter supports fungi and bacteria, which in turn support the invertebrates and blind catfish in this region of the Edwards aquifer (Longley, 1981). The food source might also be similar to that discovered at Movile Cave in Romania, which is isolated from terrestrial inputs. The energy source for the diverse community of organisms in Movile Cave appears to be hydrogen sulfide-fixing bacteria (Sarbu and others, 1996). The top of the food chain in the deeper parts of the Edwards aquifer appears to be occupied by the widemouth blindcat, *Satan eurystomus*, whose stomach contents include crustacean skeletons (Langecker and Longley, 1993). The mouthparts and stomach contents of the other catfish in the aquifer, the toothless blindcat (*Trogloglanis pattersoni*), indicate that it forages on organic matter coating the cave walls.

SUMMARY

The USGS NAWQA Program is an interdisciplinary program designed to assess water quality across the Nation using chemical, physical, and biological measures. The program is based on investigations of more than 50 study units encompassing one or more major river basins and aquifers. Intensive field investigations and retrospective reports of existing environmental data in the study units increase the understanding of the status of and trends in the resource quality of these aquatic systems. This retrospective report summarizes available information on aquatic biology of the streams and rivers in the Guadalupe, San Antonio, and Nueces River Basins, and the San Antonio-Nueces and Nueces-Rio Grande Coastal Basins, and of the Edwards aquifer where it underlies the three river basins. The biology of the study-unit streams is determined mostly by the characteristics of the ecoregions they transect. The ecoregions are the Edwards Plateau, Texas Blackland Prairies, East Central Texas Plains, Western Gulf Coastal Plain, and Southern Texas Plains.

This report summarizes in table format 32 aquatic vertebrate (primarily fish), 54 aquatic invertebrate, and

13 aquatic plant studies, published mostly during 1973–97. About 20 percent of the previous fish and invertebrate studies and about 75 percent of the aquatic plant studies have centered on Comal Springs in Comal County and San Marcos Springs in Hays County, the two largest springs in Texas. Although several important studies are available for the San Antonio region, documentation of aquatic biology of the remainder of the study unit is relatively sparse.

The SCTX study unit is unique in that it contains a diversity of both surface-water and aquifer habitats. The streams, particularly in the Edwards Plateau, support three dominant biological groups—fish, aquatic invertebrates, and plants. Potential threats to the endemic (native) species exist, such as impoundments and flood-control projects, siltation from erosion, ground-water pumping, recreational activities, wastewater discharge, and introduction of non-native species. More than 30 non-native fish, invertebrate, and plant species have been introduced into the region, including the giant ramshorn snail and blue tilapia of tropical origin that are able to survive the relatively mild and constant temperatures of springs in the study area. About 20 percent of native Texas freshwater species are in potential danger of extirpation (range reduction) or extinction. Of the 19 aquatic species Federally listed as endangered or threatened in Texas, 8 are associated with springs and spring runs in the SCTX study unit. All of the endangered species in the study unit are associated with springs and spring runs.

A large number of endemic species in the study unit are associated with subterranean aquatic ecosystems, most likely a consequence of the unique proximity of the varied topographic and hydrologic conditions of the area and of the geological development of the Edwards aquifer. Ninety-one endemics, including 44 species found solely underground, are associated with the aquatic ecosystems (including springs) of the Edwards aquifer.

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Table 1. Literature citations for biological surveys and field studies in the South-Central Texas study unit, Texas

[USGS, U.S. Geological Survey]

No. (figs. 2–5)	Citation	Type of study									Ecoregion					Subject
		Vertebrates	Invertebrates	Plants	Troglobites	Nonindigenous	Habitat	Edwards aquifer	Species of concern	Water chemistry	Edwards Plateau	Texas Blackland Prairies	East Central Texas Plains	Western Gulf Coastal Plain	Southern Texas Plains	
1	Anderson and others, 1995	X									X	X	X			Examination of changes in Texas fish community structure over 30-year period.
2	Angerstein and Lemke, 1994			X		X					X					First collections of *Hygrophila polysperma*, a potentially noxious aquatic weed, reported from Comal and San Marcos Rivers, central Texas.
3	Barr and Spangler, 1992		X		X			X			X					Description of aquatic beetle, *Stygoparnus comalensis*, and comparison with dryopid genus Helichus. First member of Dryopidae reported from subterranean waters.
4	Barra, 1976		X									X				Power-plant effluent effect on macroinvertebrate diversity in Calaveras Lake.
5	Bayer, 1975		X								X	X	X	X		Description of dragonfly (*Anisoptera*) nymphs in lentic and lotic areas, Guadalupe River Basin.
6	Bayer and others, 1992	X	X				X			X	X	X			X	Classification of smaller streams in Texas.
7	Bowles, 1994		X									X				Survey of caddisflies of Comal Springs.
8	Bowles and Short, 1988	X	X							X	X					Effect of fish predation on macroinvertebrate drift in Honey Creek.
9	Bowman and Jensen, 1977		X							X				X		Collection of field data and water samples for chemical analysis at seven sites on Nueces River.
10	Bradsby, 1994	X	X	X			X					X				Impact of recreation on upper San Marcos River.
11	Brown, 1953	X				X						X				List of introduced fish species in San Marcos, Comal, and San Antonio Springs.
12	Buzan, 1982a		X							X	X	X				Two surveys in Cibolo Creek, 1980.
13	Buzan, 1982b	X	X							X	X	X				Two surveys in Salado Creek, 1981.
14	Cover, 1980		X									X				Mayfly drift in San Marcos River.
15	Crowe and Sharp, 1997	X	X	X		X	X	X	X	X		X				Delineation of 18 distinctive habitats for endangered fountain darter in Comal Springs/River system.

Table 1. Literature citations for biological surveys and field studies in the South-Central Texas study unit, Texas—Continued

No. (figs. 2–5)	Citation	Type of study									Ecoregion					
		Verte-brates	Inverte-brates	Plants	Troglo-bites	Non-indig-enous	Habi-tat	Edwards aquifer	Species of con-cern	Water chem-istry	Edwards Plateau	Texas Black-land Prairies	East Central Texas Plains	Western Gulf Coastal Plain	South-ern Texas Plains	Subject
16	Davis, 1975	X										X				Survey of parasitic worms of western mosquitofish, *Gambusia affinis*, near San Marcos.
17	Davis, 1980	X									X					Comparison of growth of largemouth bass from selected areas of Canyon Reservoir.
18	Davis, 1982		X								X	X				Benthic macroinvertebrate diversity of three subreaches of Cibolo Creek.
19	De La Cruz, 1978		X							X					X	Collection of physical, chemical, and biological data for Nueces River.
20	De La Cruz, 1994	X	X				X			X		X				Biosurvey for impact assessment of lower Leon Creek using modified Rapid Bioassessment Protocols III and V.
21	Devall, 1940			X			X			X						Macrophytes of Spring Lake (San Marcos Springs).
22	Epperson and Short, 1987		X													Annual production of the hellgrammite, *Corydalus cornutus*, in Guadalupe River.
23	Espey, Huston and Associates, Inc., 1983	X	X							X		X	X			Examination of aquatic habitats of Medina and San Antonio Rivers.
24	Ezell, 1982		X							X	X	X				Two surveys, 1979—collection of physical, chemical, and biological data for Cibolo Creek.
25	Findeisen, 1997	X					X			X			X			Determination of fish species composition, biotic integrity, sensitivity of index of biotic integrity, and assessment of fish habitat use on lower San Antonio River at three different flows.
26	Garrett, 1991	X				X			X							Guidelines for management of Guadalupe bass.
27	Gonzales, 1988	X								X	X	X				Assessment of biotic integrity of upper San Antonio River using fish-community composition and structure.
28	C.A. Hartmann, USGS, written commun., 1995		X	X						X	X	X				Biological collections from USGS 1992–95 study of upper San Antonio River and Olmos and Salado Creeks.
29	Hershler and Longley, 1986a		X		X			X			X					Description of *Hadoceras taylori*, a phreatic snail from three localities in Real County.

Table 1. Literature citations for biological surveys and field studies in the South-Central Texas study unit, Texas—Continued

No. (figs. 2–5)	Citation	Type of study									Ecoregion					Subject
		Vertebrates	Invertebrates	Plants	Troglobites	Non-indigenous	Habitat	Edwards aquifer	Species of concern	Water chemistry	Edwards Plateau	Texas Blackland Prairies	East Central Texas Plains	Western Gulf Coastal Plain	Southern Texas Plains	
30	Hershler and Longley, 1986b	X	X		X			X	X		X					Systematic analysis of phreatic snails (hydrobiids) from 23 localities in south-central Texas.
31	Hershler and Longley, 1987		X		X			X			X					Description of new species of cavesnail, *Phreatodrobia coronae*, from spring orifices in southwestern Texas.
32	Hobbs and Hobbs, 1995		X													Description of new crayfish for Nueces River Basin.
33	Howells, 1997		X				X		X							Documentation of 7,200 unionids collected from 232 locations statewide.
34	Hubbs and others, 1953	X					X				X					Fish survey of upper Guadalupe River.
35	Jasper and Vogtsberger, 1996		X				X									Descriptions and habitat notes of some aquatic beetles.
36	Kane, 1995		X									X				Textile-mill effluent and low-water dam effects on benthic macroinvertebrate communities in Guadalupe River.
37	Kelsey, 1997	X					X					X	X			Index of biotic integrity used to assess water quality and impacts from point and nonpoint sources of pollution in San Marcos River.
38	Kent, 1971		X								X					Measurement of effects of Canyon Reservoir on benthic macroinvertebrate communities of Guadalupe River.
39	Lemke, 1989			X		X			X							List of aquatic vascular plants in San Marcos River upstream of Blanco River confluence.
40	Lewis and Bowman, 1996		X		X						X					Classification and collection sites of known subterranean asellids of Texas.
41	Lindholm, 1979		X									X				Gastropod survey of upper San Marcos River.
42	Longley, 1992	X	X		X		X	X	X		X					Aquatic fauna assemblage in Edwards aquifer. Examines threats of ground-water pumping on aquifer organisms.
43	Longley and others, 1996	X	X							X		X	X			Bathymetric, hydrological, habitat, and biological assessment of potential dam sites on Guadalupe River.

Table 1. Literature citations for biological surveys and field studies in the South-Central Texas study unit, Texas—Continued

No. (figs. 2–5)	Citation	Type of study									Ecoregion					Subject
		Vertebrates	Invertebrates	Plants	Troglobites	Nonindigenous	Habitat	Edwards aquifer	Species of concern	Water chemistry	Edwards Plateau	Texas Blackland Prairies	East Central Texas Plains	Western Gulf Coastal Plain	Southern Texas Plains	
44	Neck, 1984		X	X		X						X				Documentation of invasion of exotic giant ramshorn snail (*Marisa cornuarietis*) in San Marcos River.
45	Nelson, 1993	X					X	X	X							Population size, distribution, and life history of San Marcos salamander (*Eurycea nana*), San Marcos River.
46	Obenoskey, 1997		X	X		X	X		X			X				Effect of crayfish, *Procambarus clarkii*, on macrophytes and snails in Landa Lake.
47	Owen, 1996		X													Examination of effectiveness of River Continuum Concept as a model for Edwards Plateau streams.
48	Power, 1996			X		X			X							Potential threat of floating and submerged drifting aquatic vegetation to Texas wild rice (*Zizania texana*).
49	Power and Fonteyn, 1995			X					X							Determination of substrate preference by endangered Texas wild rice (*Zizania texana*) in Spring Lake.
50	Rathburn, 1976		X							X		X				Collection of physical, chemical, and biological data for Leon Creek.
51	Respess, 1986		X							X	X					Collection of physical, chemical, and biological data for Blanco River.
52	Richardson and Gold, 1995	X												X		Examination of samples of plateau shiners (*Cyprinella lepida*) collected in Nueces River Basin for restriction site variation of mitochondrial DNA.
53	San Antonio River Authority, 1996	X	X				X			X	X	X	X			Evaluation of biological communities as an indicator parameter for water quality in San Antonio River watershed.
54	Schenck, 1975	X							X			X				Ecology of endangered fountain darter in upper San Marcos River.
55	Schenck and Whiteside, 1976	X							X			X				Distribution, habitat preference, and population size estimate of fountain darter (*Etheostoma fonticola*) in San Marcos River.
56	Schenck and Whiteside, 1977a	X							X			X				Food habits and feeding behavior of endangered fountain darter (*Etheostoma fonticola*) in San Marcos River.

Table 1. Literature citations for biological surveys and field studies in the South-Central Texas study unit, Texas—Continued

No. (figs. 2–5)	Citation	Type of study									Ecoregion					
		Vertebrates	Invertebrates	Plants	Troglobites	Nonindigenous	Habitat	Edwards aquifer	Species of concern	Water chemistry	Edwards Plateau	Texas Blackland Prairies	East Central Texas Plains	Western Gulf Coastal Plain	Southern Texas Plains	Subject
57	Short, 1982	X	X								X					Diel changes in water temperature, dissolved oxygen, conductivity, invertebrate drift, invertebrate food habits, and fish food habits in Guadalupe River.
58	Short and Smith, 1989		X								X					Seasonal comparison of processing of hackberry leaves indicating temperature as primary factor influencing processing rate in Honey Creek.
59	Solanik, 1996		X								X	X				Effect of season and intermittency on patterns of longitudinal variation in macroinvertebrate taxonomic and functional feeding group composition of Cibolo Creek.
60	Stanley, 1986		X								X		X			Distribution, life histories, and production of mayflies in Guadalupe River Basin.
61	Stanley and Short, 1988		X								X					Determination of efficacy of thermal equilibrium hypothesis with warmwater insects in Blanco River and Honey Creek (Guadalupe River Basin).
62	Staton, 1992			X		X										Determination of recent negative impacts in aquatic macrophyte community in San Marcos River and projection of effect on aquatic flora.
63	Stock and Longley, 1981		X		X			X			X					Distribution of only known North American thermosbaenacean, *Monodella texana* Maguire.
64	Strenth, 1976		X		X			X			X					Troglobitic shrimp from Ezell's Cave in San Marcos.
65	Strenth and Longley, 1990		X		X			X			X					Determination of absence of seasonal period of reproduction in subterranean shrimp, *Palaemonetes antrorum*, from Central Texas.
66	Taylor, 1995/ Taylor and Ferreira, 1995		X	X			X			X		X				Biological survey of benthic macroinvertebrates, periphyton, and phytoplankton, community characteristics, and associated water quality for lower Olmos Creek and upper San Antonio River.

Table 1. Literature citations for biological surveys and field studies in the South-Central Texas study unit, Texas—Continued

No. (figs. 2–5)	Citation	Type of study									Ecoregion					Subject
		Verte-brates	Inverte-brates	Plants	Troglo-bites	Non-indig-enous	Habi-tat	Edwards aquifer	Species of con-cern	Water chem-istry	Edwards Plateau	Texas Black-land Prairies	East Central Texas Plains	Western Gulf Coastal Plain	South-ern Texas Plains	
67	Terre and Magnelia, 1996	X				X					X	X				Sport fish stocking histories and sampling results in Guadalupe River.
68	Terre and Magnelia, 1997	X									X					Physical and historical data, habitat survey, stocking history, location of sites, water levels, species information, and fisheries management plan for Canyon Reservoir.
69	Texas System of Natural Laboratories, Inc., 1994	X														Taxonomic and distributional inventory of freshwater and marine fishes of Texas with bibliography.
70	Tiemann, 1992		X								X	X				Caddisfly diversity and life histories in streams on Edwards Plateau.
71	Tomme, 1974		X							X		X				Collection of physical, chemical, and biological data for Cibolo Creek.
72	Trebatoski, 1991	X					X							X		Investigation of potential impact of municipal-wastewater discharge into Guadalupe River.
73	Twidwell, 1975		X							X			X	X		Collection of physical, chemical, and biological data for San Antonio River.
74	Twidwell, 1976		X							X		X				Collection of physical, chemical, and biological data for Medina River.
75	Twidwell, 1984	X	X							X			X	X		Two surveys, 1983—collection of physical, chemical, and biological data (fish and benthic macroinvertebrates) for San Antonio River.
76	Twidwell, 1987		X							X	X					Hydrology, field measurements, water chemistry, and benthic macroinvertebrates for Guadalupe River.
77	Twidwell and Davis, 1987		X							X		X	X	X		Four seasonal surveys of San Antonio River.
78	U.S. Fish and Wildlife Service, 1995	X	X	X	X		X	X	X		X					Development of recovery plan for aquatic endangered species in San Marcos and Comal Springs.

Table 2. Fish collected in streams of the South-Central Texas study unit, Texas

[From Texas System of Natural Laboratories, Inc. (1994). River basin: G, Guadalupe; SA, San Antonio; N, Nueces; SN, San Antonio-Nueces Coastal; NR, Nueces-Rio Grande Coastal]

Order Family Common name	Genus	River basin
Lepisosteiformes		
Lepisosteidae (gars)		
Spotted gar	*Lepisosteus oculatus*	G, SA, N, SN, NR
Longnose gar	*Lepisosteus osseus*	G, SA, N, SN, NR
Alligator gar	*Lepisosteus spatula*	G, SA, N, SN, NR
Anguilliformes		
Anguillidae (freshwater eels)		
American eel	*Anguilla rostrata*	G, SA, N, SN, NR
Clupeiformes		
Clupeidae (herrings)		
Skipjack herring	*Alosa chrysochloris*	G, SA
American shad	*Alosa sapidissima*	G, SA
Gizzard shad	*Dorosoma cepedianum*	G, SA, N, SN, NR
Threadfin shad	*Dorosoma petenense*	G, SA, N, SN, NR
Engraulidae (anchovies)		
Bay anchovy	*Anchoa mitchilli*	N, SN, NR
Cypriniformes		
Cyprinidae (carps and minnows)		
Central stoneroller	*Campostoma anomalum*	G, SA, N
Mexican stoneroller	*Campostoma ornatum*	N
Goldfish	*Carassius auratus*	G, N
Plateau shiner	*Cyprinella lepida*	G, N
Red shiner	*Cyprinella lutrensis*	G, SA, N, SN
Blacktail shiner	*Cyprinella venusta*	G, SA, N
Common carp	*Cyprinus carpio*	G, SA, N, NR
Roundnose minnow	*Dionda episcopa*	G, N
Nueces roundnose minnow	*Dionda serena*	SA, N
Plains minnow	*Hybognathus placitus*	G
Speckled chub	*Macrhybopsis aestivalis*	G, SA, N
Golden shiner	*Notemigonus crysoleucas*	G, SA, N
Texas shiner	*Notropis amabilis*	G, SA, N
Pallid shiner	*Notropis amnis*	G, SA
Blackspot shiner	*Notropis atrocaudalis*	G, SA
River shiner	*Notropis blennius*	SA
Ghost shiner	*Notropis buchanani*	G, SA, N
Ironcolor shiner	*Notropis chalybaeus*	G
Sand shiner	*Notropis stramineus*	G, SA, N
Weed shiner	*Notropis texanus*	G, SA, N
Mimic shiner	*Notropis volucellus*	G, SA, N
Pugnose minnow	*Opsopoeodus emiliae*	G, SA, N
Suckermouth minnow	*Phenacobius mirabilis*	N
Bluntnose minnow	*Pimephales notatus*	N
Fathead minnow	*Pimephales promelas*	G, SA

Table 2. Fish collected in streams of the South-Central Texas study unit, Texas—Continued

Order Family Common name	Genus	River basin
Cypriniformes—Continued		
Cyprinidae (carps and minnows)—Continued		
Bullhead minnow	*Pimephales vigilax*	G, SA, N
Tench	*Tinca tinca*	G
Catostomidae (suckers)		
River carpsucker	*Carpiodes carpio*	G, SA, N, SN, NR
Creek chubsucker	*Erimyzon oblongus*	G
Lake chubsucker	*Erimyzon sucetta*	G
Smallmouth buffalo	*Ictiobus bubalus*	G, SA, N, SN, NR
Spotted sucker	*Minytrema melanops*	G
Gray redhorse	*Moxostoma congestum*	G, SA, N
Characiformes		
Characidae (characins)		
Mexican tetra	*Astyanax mexicanus*	G, SA, N, NR
Siluriformes		
Ictaluridae (bullhead catfishes)		
Black bullhead	*Ameiurus melas*	G, SA, N, SN, NR
Yellow bullhead	*Ameiurus natalis*	G, SA, N, SN, NR
Brown bullhead	*Ameiurus nebulosus*	G, SA, N, NR
Blue catfish	*Ictalurus furcatus*	G, SA, N, SN, NR
Headwater catfish	*Ictalurus lupus*	SA, N
Channel catfish	*Ictalurus punctatus*	G, SA, N, SN, NR
Tadpole madtom	*Noturus gyrinus*	SA, N, SN
Flathead catfish	*Pylodictis olivaris*	G, SA, N
Widemouth blindcat	*Satan eurystomus*	SA
Toothless blindcat	*Trogloglanis pattersoni*	SA
Ariidae (sea catfishes)		
Hardhead catfish	*Arius felis*	G, SN, NR
Gafftopsail catfish	*Bagre marinus*	NR
Loricariidae (suckermouth catfishes)		
Suckermouth catfish	*Hypostomus plecostomus*	SA
Atheriniformes (Cyprinodontiformes)		
Cyprinodontidae (killifishes)		
Diamond killifish	*Adinia xenica*	N, NR
Sheepshead minnow	*Cyprinodon variegatus*	G, SA, SN, NR
Gulf killifish	*Fundulus grandis*	G, N, SN, NR
Blackstripe topminnow	*Fundulus notatus*	G, SA
Bayou killifish	*Fundulus pulvereus*	G, N, SN, NR
Longnose killifish	*Fundulus similis*	SN, NR
Plains killifish	*Fundulus zebrinus*	N
Rainwater killifish	*Lucania parva*	G, SA, N, SN, NR
Poeciliidae (livebearers)		
Pike killifish	*Belonesox belizanus*	SA
Western mosquitofish	*Gambusia affinis*	G, SA, N, SN, NR
Largespring gambusia	*Gambusia geiseri*	G
San Marcos gambusia	*Gambusia georgei*	G, N

Table 2. Fish collected in streams of the South-Central Texas study unit, Texas—Continued

Order Family Common name	Genus	River basin
Atheriniformes (Cyprinodontiformes)—Continued		
Poeciliidae (livebearers)—Continued		
Amazon molly	*Poecilia formosa*	G, SA, N
Sailfin molly	*Poecilia latipinna*	G, SA, N, SN, NR
Atherinidae (silversides)		
Rough silverside	*Membras martinica*	SN
Inland silverside	*Menidia beryllina*	G, SN, NR
Atlantic silverside	*Menidia menidia*	SN
Zeiformes		
Syngnathidae (pipefishes)		
Gulf pipefish	*Syngnathus scovelli*	SN, NR
Perciformes		
Centropomidae (snooks)		
Common snook	*Centropomus undecimalis*	N
Percichthyidae (temperate basses)		
White bass	*Morone chrysops*	G, SA
Centrarchidae (sunfishes)		
Rock bass	*Ambloplites rupestris*	G
Flier	*Centrarchus macropterus*	SA
Banded pygmy sunfish	*Elassoma zonatum*	SA
Redbreast sunfish	*Lepomis auritus*	G, SA, N
Green sunfish	*Lepomis cyanellus*	G, SA, N, SN, NR
Warmouth	*Lepomis gulosus*	G, SA, N, SN, NR
Bluegill	*Lepomis macrochirus*	G, SA, N, SN, NR
Longear sunfish	*Lepomis megalotis*	G, SA, N, SN, NR
Redear sunfish	*Lepomis microlophus*	G, SA, N, SN, NR
Spotted sunfish	*Lepomis punctatus*	G, SA, N
Smallmouth bass	*Micropterus dolomieu*	G
Spotted bass	*Micropterus punctulatus*	G, SA
Largemouth bass	*Micropterus salmoides*	G, SA, N, SN, NR
Guadalupe bass	*Micropterus treculi*	G, SA
White crappie	*Pomoxis annularis*	G, SA, N, SN, NR
Black crappie	*Pomoxis nigromaculatus*	G, SA, N
Salmonidae (salmon and trout)		
Rainbow trout	*Oncorhynchus mykiss*	G
Brown trout	*Salmo trutta*	G
Brook trout	*Salvelinus fontinalis*	G
Percidae (perches)		
Bluntnose darter	*Etheostoma chlorosomum*	G, SA
Fountain darter	*Etheostoma fonticola*	G
Swamp darter	*Etheostoma fusiforme*	N
Slough darter	*Etheostoma gracile*	G, SA, N
Greenthroat darter	*Etheostoma lepidum*	G, SA, N
Orangethroat darter	*Etheostoma spectabile*	G, SA, N
Logperch	*Percina caprodes*	G, SA
Texas logperch	*Percina carbonaria*	G, SA

Table 2. Fish collected in streams of the South-Central Texas study unit, Texas—Continued

Order Family Common name	Genus	River basin
Perciformes—Continued		
Percidae (perches)—Continued		
Bigscale logperch	*Percina macrolepida*	G
Dusky darter	*Percina sciera*	G
River darter	*Percina shumardi*	G, SA
Sparidae (porgies)		
Sheepshead	*Archosargus probatocephalus*	N
Pinfish	*Lagodon rhomboides*	SN
Sciaenidae (drums)		
Freshwater drum	*Aplodinotus grunniens*	N, NR
Silver perch	*Bairdiella chrysoura*	SN, NR
Sand seatrout	*Cynoscion arenarius*	N
Spotted seatrout	*Cynoscion nebulosus*	G, N
Silver seatrout	*Cynoscion nothus*	N
Spot	*Leiostomus xanthurus*	G
Atlantic croaker	*Micropogonias undulatus*	N, SN, NR
Black drum	*Pogonias cromis*	G, N, SN, NR
Red drum	*Sciaenops ocellatus*	G
Cichlidae (cichlids)		
Rio Grande cichlid	*Cichlasoma cyanoguttatum*	G, SA, N, SN, NR
Blue tilapia	*Tilapia aurea*	G, SA
Mozambique tilapia	*Tilapia mossambica*	G, SA
Redbelly tilapia	*Tilapia zilli*	SA
Mugilidae (mullets)		
Mountain mullet	*Agonostomus monticola*	G, SA, N
Striped mullet	*Mugil cephalus*	G, SA, N, SN, NR
White mullet	*Mugil curema*	G, SA, SN
Eleotridae (sleepers)		
Fat sleeper	*Dormitator maculatus*	SN
Spinycheek sleeper	*Eleotris pisonis*	N
Bigmouth sleeper	*Gobiomorus dormitor*	SN
Gobiidae (gobies)		
Freshwater goby	*Gobionellus shufeldti*	G
Naked goby	*Gobiosoma bosc*	G, N, SN
Code goby	*Gobiosoma robustum*	G, NR
Clown goby	*Microgobius gulosus*	G
Green goby	*Microgobius thalassinus*	G
Pleuronectiformes		
Bothidae (lefteye flounders)		
Southern flounder	*Paralichthys lethostigma*	G, N, SN, NR
Soleidae (soles)		
Lined sole	*Achirus lineatus*	NR
Blackcheek tonguefish	*Symphurus plagiusa*	NR
Hogchoker	*Trinectes maculatus*	N, SN
Tetraodontiformes		
Tetraodontidae (puffers)		
Least puffer	*Sphoeroides parvus*	N, SN, NR

Table 3. Aquatic invertebrates collected in streams of the South-Central Texas study unit, Texas

[From Bayer and others (1992); Davis (1982); Richerson (1982); Taylor (1995); and Taylor and Ferreira (1995). River basin: SA, San Antonio; G, Guadalupe; N, Nueces. Ecoregion: EP, Edwards Plateau; STP, Southern Texas Plains; TBP, Texas Blackland Prairies; ECTP, East Central Texas Plains. N/D, not determined]

Class Order Family	Genus	River basin	Ecoregion
Arachnoidea			
Hydracarina			
Limnocharidae	*Limnochares* sp.	SA	EP
Crustacea			
Amphipoda			
Talitridae	*Hyalella azteca*	G	EP
Ostracoda (Podocopa)			
Cyprididae	*Chlamydotheca arcuata*	G	EP
	Herpetocypris nr. *reptans*	SA	EP
	Stenocypris nr. *malcolmsoni*	G	EP
Darwinulidae	*Darwinula stevensoni*	N	STP
Limnocytheridae	*Limnocythere* sp.	N	STP
Gastropoda			
Limnophila (Pulmonates)			
Ancylidae	*Ferrissia rivularis*	G	EP
	Hebetancylus excentricus	SA	TBP
Lymnaeidae	*Fossaria parva*	G, N	EP, STP
	Pseudosuccinea columella	N	STP
Physidae	*Physa* sp.	SA	TBP
	Physella virgata	G, N	EP, STP
Planorbidae	*Biomphalaria obstructus*	G	EP
	Gyraulus parvus	N	STP
	Gyraulus sp.	SA	TBP
	Planorbella trivolvis	N	STP
Mesogastropoda			
Hydrobiidae	*Cincinnatia cincinnatiensis*	G	EP, TBP
	Pyrgophorus spinosus	N	STP
Hirudinea			
Rhynchobdellida			
Glossiphoniidae	*Glossiphonia heteroclita*	SA	TBP
	Helobdella fusca	SA	TBP
	Helobdella stagnalis	G	EP
Insecta (Hexopoda)			
Coleoptera			
Dryopidae	*Helichus suturalis*	SA	EP
	Haideoporus texanus	G	EP
	Hydroporus sp.	N	STP
Elmidae	*Elsianus texanus*	G	EP, TBP
	Hexacylloepus ferrugineus	G, SA	EP, TBP
	Microcylloepus sp.	G, SA, N	EP, TBP, STP

Table 3. Aquatic invertebrates collected in streams of the South-Central Texas study unit, Texas—Continued

Class / Order / Family	Genus	River basin	Ecoregion
Insecta (Hexopoda)—Continued			
Coleoptera—Continued			
Elmidae—Continued	*Microcylloepus pusillus*	G, SA, N	EP, TBP, STP
	Neoelmis caesa	G, SA	EP, TBP
	Stenelmis occidentalis	G, SA	EP TBP
	Stenelmis sexlineata	G, SA	TBP
	Stenelmis sp.	G, SA	EP, TBP, STP
Gyrinidae	*Dineutus* sp.	N	STP
Hydrophilidae	*Enochrus* sp.	G	EP
Limnichidae	*Lutrochus luteus*	SA	EP
Scirtidae	*Cyphon* sp.	N	STP
	Labrundinia sp.	SA	TBP
Diptera			
Ceratopogonidae	*Bezzia* sp.	SA	EP
	Palpomyia tibialis	G, SA	EP
	Probezzia sp.	G, SA	EP, TBP
Chironomidae	*Cardiocladius* sp.	SA	EP
	Chironomus riparius gr.	N	STP
	Cladotanytarsus mancus gr.	N	STP
	Corynoneura sp.	SA	TBP
	Cricotopus bicinctus	G	TBP
	Cricotopus sp.	G, SA	EP, TBP
	Cricotopus trifacia	SA	TBP
	Dicrotendipes neomodestus	N	STP
	Dicrotendipes nr. *notatus*	G	EP
	Dicrotendipes sp.	SA, N	TBP, STP
	Einfeldia sp.	SA	TBP
	Glyptotendipes sp. gr. A	N	STP
	Goeldichironomus holoprasinus	N	STP
	Lauterborniella agrayloides	G	EP
	Nanocladius rectinervis	SA	EP
	Orthocladius sp.	G, SA	EP, TBP
	Parachironomus arcuatus gr.	N	STP
	Parametriocnemus sp.	G	EP
	Phaenopsectra sp.	N	STP
	Polypedilum convictum	G	EP
	Polypedilum illinoense	N	STP
	Polypedilum sp.	SA	TBP
	Pseudochironomus sp.	G, SA	EP, TBP
	Rheocricotopus fuscipes gr.	G, SA	EP, TBP
	Rheotanytarsus exiguus gr.	G, SA	EP
	Tanytarsus guerlus gr.	G, N	EP, STP
	Tanytarsus sp.	SA	TBP

Table 3. Aquatic invertebrates collected in streams of the South-Central Texas study unit, Texas—Continued

Class / Order / Family	Genus	River basin	Ecoregion
Insecta (Hexopoda)—Continued			
Diptera—Continued			
Chironomidae—Continued	*Thienemanniella* nr. *xena*	SA, N	EP, STP
	Thienemanniella sp.	SA	TBP
	Thienemannimyia sp.	SA	TBP
	Zavrelimyia sp.	SA	TBP
Culicidae	*Culex* sp.	G	EP
Empididae	*Hemerodromia* sp.	G, SA, N	EP, TBP, STP
Simuliidae	*Simulium* nr. *bivittatum*	N	STP
	Simulium nr. *trivittatum*	SA	EP
	Simulium sp.	G, SA, N	EP, TBP
Tabanidae	*Tabanus* sp.	G	EP
Tanypodinae	*Larsia* sp.	G	EP
	Natarsia punctata	G	EP
	Pentaneura sp.	G	EP
Tipulidae	*Antocha* sp.	SA	TBP
	Geranomyia sp.	G	EP
	Tipula sp.	SA	TBP
Ephemeroptera			
Baetidae	*Baetis alius*	SA	TBP
	Baetis sp.	N	EP
	Baetodes edmundsi	SA	EP
	Baetodes sp.	G	TBP
	Dactylobaetis mexicanus	G, SA	EP, TBP
	Fallceon quilleri	G, SA, N	EP, TBP, STP
Caenidae	*Caenis hilaris* (Say)	G	EP
	Caenis sp.	G, SA, N	EP, STP
Leptophlebiidae	*Thraulodes gonzalesi*	G, SA	EP, TBP
	Traverella presidiana	G, SA	EP, TBP
Oligoneuriidae	*Isonychia sicca manca*	G, SA	EP, TBP
Tricorythidae	*Leptohyphes packeri*	G	TBP
	Leptohyphes succinus	SA	EP
	Leptohyphes vescus	SA	EP
	Tricorythodes albilineatus gr.	G, SA	EP, TBP
	Tricorythodes curvatus gr.	SA	EP
Hemiptera			
Hebridae	*Merragata* sp.	G	EP
Naucoridae	*Ambrysus circumcinctus*	G, SA	EP, TBP
Lepidoptera			
Pyralidae	*Parapoynx* sp.	G	EP
	Parargyractis sp.	G, SA	EP, TBP
Megaloptera			
Corydalidae	*Corydalus cornutus*	SA	EP

Table 3. Aquatic invertebrates collected in streams of the South-Central Texas study unit, Texas—Continued

Class Order Family	Genus	River basin	Ecoregion
Insecta (Hexopoda)—Continued			
Odonata			
Calopterygidae	*Hetaerina* sp.	G, SA	EP
Coenagrionidae	*Argia bipunctulata*	SA	TBP
	Argia immunda (Hagen)	G	TBP
	Argia sp.	G, SA, N	EP, TBP, STP
	Argia translata Hagen	G, SA, N	EP, TBP
	Enallagma sp.	G	TBP
	Ischnura sp.	N	STP
Gomphidae	*Erpetogomphus* sp.	G	TBP
Libellulidae	*Brechmorhoga mendax*	G, SA	EP, TBP
Trichoptera			
Calamoceratidae	*Phylloicus ornatus*	G	EP
Ecnomidae	*Austrotinodes texensis*	SA	EP
Glossosomatidae	*Protoptila alexanderi*	G	EP
	Protoptila sp.	G	TBP
Helicopsychidae	*Helicopsyche borealis*	G	EP
	Helicopsyche piroa Ross	G, SA	EP, TBP, ECTP
Hydrobiosidae	*Atopsyche erigia* Ross	G	EP, ECTP
Hydropsychidae	*Cheumatopsyche comis*	G	EP
	Cheumatopsyche pettiti	G	EP
	Cheumatopsyche sp.	G, SA, N	EP, TBP
	Hydropsyche bidens	N	EP
	Hydropsyche orris	G	EP
	Hydropsyche simulans	G, SA, N	EP, TBP
	Hydropsyche sp.	G, SA	EP
	Smicridea fasciatella	G, SA, N	EP, STP
	Smicridea sp.	G, SA, N	EP, TBP
Hydroptilidae	*Hydroptila ajax*	G	EP
	Hydroptila angusta	G	EP
	Hydroptila melia	G	TBP
	Hydroptila protera	N	EP
	Hydroptila sp.	G, SA, N	EP, TBP, STP
	Hydroptila waubesiana	G	EP
	Leucotrichia sarita Ross	G	EP
	Leucotrichia sp.	G	TBP
	Mayatrichia nr. *ayama*	SA	EP
	Mayatrichia nr. *ponta*	SA	EP
	Neotrichia edalis Ross	G	EP
	Neotrichia sp.	G, SA	EP, TBP
	Neotrichia vibrans Ross	G	TBP
	Ochrotrichia nigritta	G	EP
	Ochrotrichia sp.	G, SA, N	EP, TBP

Table 3. Aquatic invertebrates collected in streams of the South-Central Texas study unit, Texas—Continued

Class / Order / Family	Genus	River basin	Ecoregion
Insecta (Hexopoda)—Continued			
Trichoptera—Continued			
Hydroptilidae—Continued	*Ochrotrichia tarsalis*	G	EP
	Oxyethira azteca (Mosely)	G	EP
	Oxyethira pallida (Banks)	G	EP
	Oxyethira sp.	G, SA, N	EP, TBP
	Oxyethira ulmeri	G, N	EP
Leptoceridae	*Nectopsyche gracilis*	G	EP, TBP
	Nectopsyche pavida	G	TBP
	Nectopsyche sp.	G, SA	TBP
	Oecetis avara	G, SA	EP, TBP
	Oecetis inconspicua	G	EP
	Oecetis persimilis	G, N	EP
	Oecetis sp.	G, SA	EP
	Triaenodes ignitus	G	EP
Philopotamidae	*Chimarra beameri*	N	EP
	Chimarra feria	G	EP
	Chimarra obscura	G	EP
	Chimarra sp.	G, SA, N	EP, TBP
	Chimarra texana	G	EP
Polycentropodidae	*Polycentropus* sp.	SA	EP
	Polyplectropus charlesi	G	TBP
	Polyplectropus proditus	G, SA	EP
Nematoda		G	EP
Nemertea	*Prostoma rubrum*	G, SA	EP, TBP
Oligochaeta			
Haplotaxida			
Enchytraeidae	N/D	N	STP
Glossoscolecidae	*Sparganophilus tamesis*	G, SA	EP
Naididae	*Slavina appendiculata*	G, SA	EP
Tubificidae	*Branchiura sowerbyi*	G, SA	EP, TBP
	Limnodrilus hoffmeisteri	N	STP
	Limnodrilus sp.	G, N	EP, STP
Lumbriculidae	N/D	SA	TBP
Pelecypoda (Bivalvia)			
Corbiculidae	*Corbicula fluminea*	G, SA, N	EP, TBP, STP
Sphaeriidae	*Eupera cubensis*	G	EP
	Musculium sp.	SA	TBP
	Pisidium nitidum	G	EP
Tubellaria			
Tricladida			
Planariidae	*Dugesia tigrina*	G, SA	EP, TBP
	Phagocata sp.	SA	TBP

Table 4. Aquatic macrophytes in aquatic habitats of the South-Central Texas study unit, Texas

[From Lemke (1989)]

Division Family	Genus	Division Family	Genus
Anthophyta		Anthophyta—Continued	
Acanthaceae	*Hygrophila lacustris*	Onagraceae	*Ludwigia repens*
Alismataceae	*Sagittaria platyphylla*	Poaceae	*Zizania texana*
Araceae	*Pistia stratiotes*	Pontederiaceae	*Eichhornia crassipes*
Ceratophyllaceae	*Ceratophyllum demersum*		*Heteranthera liebmannii*
Haloragaceae	*Myriophyllum brasiliense*	Potamogetonaceae	*Potamogeton crispus*
	Myriophyllum hererophyllum		*Potamogeton illinoensis*
	Myriophyllum spicatum		*Potamogeton nodosus*
Hydrocharitaceae	*Egeria densa*		*Potamogeton pectinatus*
	Hydrilla verticillata	Scrophulariaceae	*Limnophila sessiflora*
	Vallisneria americana	Zannichelliaceae	*Zannichellia palustris*
Lemnaceae	*Lemna minor*	Bryophyta	
	Spirodela polyrhiza	Hypnaceae	*Amblystegium riparium*
	Wolffia papulifera	Ricciaceae	*Riccia fluitans*
Lentibulariaceae	*Utricularia gibba*	Pterophyta	
Najadaceae	*Najas guadalupensis*	Parkeriaceae	*Ceratopteris thalictroides*
Nymphacaceae	*Cabomba caroliniana*	Salviniaceae	*Azolla caroliniana*
	Nuphar luteum		

Table 5. Non-native species in aquatic habitats of the South-Central Texas study unit, Texas

[From Bowles and Arsuffi (1993); Howells (1997); and U.S. Fish and Wildlife Service (1995). --, not known or not applicable]

Phylum (division) Family	Genus	Common name	Mechanism of introduction
Anthophyta			
Araceae	*Colocasia esculenta*	Wild taro	--
	Pistia stratiotes	Water lettuce	--
Haloragaceae	*Myriophyllum brasiliense*	Parrotfeather	aquaria
	Myriophyllum spicatum	Eurasian watermilfoil	aquaria
Hydrocharitaceae	*Egeria densa*	Giant waterweed	aquaria
	Hydrilla verticillata	African elodea	aquaria
Pontederiaceae	*Eichhornia crassipes*	Water hyacinth	ornamental
Potamogetonaceae	*Potamogeton crispus* L.	Curly pondweed	--
Scrophulariaceae	*Limnophila sessiflora*	--	aquaria
Chordata			
Centrarchidae	*Ambloplites rupestris*	Rock bass	game fish
	Lepomis auritus	Redbreast sunfish	game fish
	Micropterus dolomieu	Smallmouth bass	game fish
Characidae	*Astyanax mexicanus*	Mexican tetra	--
Cichlidae	*Cichlasoma cyanoguttatum*	Rio Grande cichlid	pond fish
	Tilapia aurea	Blue tiliapia	aquaria
	Tilapia mossambica	Mozambique tilapia	aquaria
	Tilapia zilli	Redbelly tilapia	aquaria
Cyprinidae	*Carassius auratus*	Goldfish	aquaria
	Ctenopharyngodon idella	Grass carp	plant control
	Cyprinus carpio	Common carp (koi)	pond fish

Table 5. Non-native species in aquatic habitats of the South-Central Texas study unit, Texas—Continued

Phylum (division) Family	Genus	Common name	Mechanism of introduction
Chordata—Continued			
Cyprinodontidae	*Cyprinodon variegatus*	Sheepshead minnow	bait
Loricariidae	*Hypostomus plecostomus*	Suckermouth catfish	aquaria
	Myocastor coypus	Nutria	fur production
Percichthyidae	*Morone saxatilis*	Striped bass	game fish
Percidae	*Stizostedion vitreum*	Walleye	game fish
Poeciliidae	*Poecilia formosa*	Amazon molly	bait/aquaria
	Poecilia latipinna	Sailfin molly	bait
	Poecilia reticulata	Guppy	aquaria
Salmonidae	*Oncorhynchus mykiss*	Rainbow trout	game fish
	Salmo trutta	Brown trout	game fish
	Salvelinus fontinalis	Brook trout	game fish
Mollusca			
Ampullariidae	*Marisa cornuarietis*	Giant ramshorn snail	aquaria
Corbiculidae	*Corbicula fluminaea*	Asiatic clam	--
Thiaridae	*Melanoides granifera*	Quilted Melania	aquaria
	Melanoides tuberculata	Red-rimmed melania	aquaria
Pterophyta			
Parkeriaceae	*Ceratopteris thalictroides*	Water sprite	aquaria
Order family	**Genus**	**Common name**	**Mechanism of introduction**
Rodentia			
Myocastoridae	*Myocastor coypus*	Nutria	fur production

Table 6. Federal and State listed endangered and threatened species in aquatic habitats of the South-Central Texas study unit, Texas

[From Campbell (1995); U.S. Fish and Wildlife Service (1997). E, endangered; T, threatened]

Phylum (division) Family	Genus	Common name	Federally listed	State listed
Anthophyta				
Gramineae	*Zizania texana*	Texas wild rice	E	
Arthropoda				
Crangonyctidae	*Stygobromus pecki*	Peck’s cave amphipod	E	
Dryopidae	*Stygoparnus comalensis*	Comal Springs dryopid beetle	E	
Elmidae	*Heterelmis comalensis*	Comal Springs riffle beetle	E	
Chordata				
Catostomidae	*Cycleptus elongatus*	Blue sucker		T
Ictaluridae	*Satan eurystomus*	Widemouth blindcat		T
	Trogloglanis pattersoni	Toothless blindcat		T
Microhylidae	*Hypopachus variolosus*	Sheep frog		T
Percidae	*Etheostoma fonticola*	Fountain darter	E	E
Plethodontidae	*Eurycea latitans*	Cascade Caverns salamander		T
	Eurycea nana	San Marcos salamander	T	T
	Eurycea tridentifera	Comal blind salamander		T
	Typhlomolge rathbuni	Texas blind salamander	E	E
	Typhlomolge robusta	Blanco blind salamander		E
Poeciliidae	*Gambusia georgei*	San Marcos gambusia	E	E

Table 7. Troglobitic species of the Edwards aquifer in the South-Central Texas study unit, Texas

[From Bowles and Arsuffi (1993); Longley (1986)]

Class / Order / Family	Genus	Class / Order / Family	Genus
Turbellaria		Crustacea—Continued	
Tricladida		Isopoda	
Planariidae	*Sphalloplana kutscheri*	Asellidae	*Asellus pilus*
	Sphalloplana mohri		*Asellus redelli*
	Sphalloplana sloani		*Lirceolus smithi*
	Sphalloplana zeschi	Cirolanidae	*Cirolanides texensis*
Ostracoda		Thermosbaenacea	
Podocopida		Monodellidae	*Monodella texana*
Cypridopsidae	*Cypridopsis vidua obesa*	Gastropoda	
Entocytheridae	*Sphaeromicola moria*	Mesogastropoda	
Copepoda		Hydrobiidae	*Balconorbis uvaldensis*
Harpacticoida			*Phreatodrobia conica*
Cyclopidae	*Cyclops cavernarum*		*Phreatodrobia imitata*
	Cyclops learii		*Phreatodrobia micra*
	Cyclops varicans rebellus		*Phreatodrobia nugax inclinata*
Crustacea			*Phreatodrobia nugax nugax*
Amphipoda			*Phreatodrobia plana*
Artesiidae	*Artesia subterranea*		*Phreatodrobia punctata*
Bogidiellidae	*Parabogidiella americana*		*Phreatodrobia rotunda*
Crangonyctidae	*Stygobromus balconis*		*Stygopyrgus bartonensus*
	Stygobromus bifurcatus	Insecta (Hexopoda)	
	Stygobromus flagellatus	Coleoptera	
	Stygobromus pecki	Dryopidae	*Stygoparnus comalensis*
	Stygobromus russelli	Dytiscidae	*Hadeoporus texanus*
Hadziidae	*Allotexiweckelia hirsuta*	Osteichthyes	
	Texiweckelia insolita	Siluriformes	
	Texiweckelia samacos	Ictaluridae	*Satan eurystomus*
	Texiweckelia texensis		*Trogloglanis pattersoni*
Sebidae	*Seborgia relicta*	Amphibia	
Decapoda		Caudata	
Palaemonidae	*Palaemonetes antrorum*	Ambystomidae	*Typhlomolge (Eurycea) rathbuni*
	Palaemonetes holthuisi		*Typhlomolge (Eurycea) robusta*

District Chief
U.S. Geological Survey
8027 Exchange Dr.
Austin, TX 78754–4733